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REPORT 1522-12

REPORT

by

THE OHIO STATE UNIVERSITY RESEARCH FOUNDATION
COLUMBUS, OHIO 43212

Sponsor U. S. Navy Electronics Laboratory
Code 3300b
San Diego, California

Contract No. N123(953) -31663A

Investigation of Study Program Related to Shipboard
Antenna System Environment

Subject of Report Pattern Handbook
Volume II: Memorandum on Shipboard
Antenna Far-field Pattern Prediction

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Date 1 July 1965

ABSTRACT

Previous work on this contract produced a method for predicting the far-field pattern in the horizontal plane of a thin vertical antenna in the presence of conducting cylinders of arbitrary cross-section. However, this technique appeared to be valid only if the scatterer was taller than the antenna. This memorandum discusses an extensive set of measurements that show the influence of the scatterer to antenna height ratio on the far-field pattern, and also how the actual antenna height itself influences what this ratio should be. Thus, the limits of validity for representing finite height configurations with infinitely tall ones are now more closely defined.

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MEMORANDUM ON SHIPBOARD ANTENNA FAR-FIELD PATTERN PREDICTION

I. INTRODUCTION

The results of the research presented in this memorandum supplement the work in Technical Report 1522-11¹ which describes a method for predicting the far-field pattern in the horizontal plane of a thin vertical radiator in the presence of cylindrical scatterers of arbitrary cross-section. This method is based on approximating the antenna with an infinite line source and the scatterer with an array of thin infinite wires.

Previously, the effect of the ratio of the scatterer height to antenna height on the far-field pattern was not well established. However, it had been observed in a limited number of cases that if the scatterer was at least twice as tall as the source antenna, the parallel infinite wire technique predicted the far-field pattern with good accuracy.

This memorandum discusses the results of an extensive set of measurements for source antenna heights of $1/8$, $1/4$, $3/8$, $1/2$, $5/8$, and $3/4$ wavelength and scatterers of similar heights. The measurements were taken on the ground plane shown in Fig. 3 of Technical Report 1522-11. The scatterer height was varied by using square cylinders of the same cross-section but of various heights while keeping the distance, d , constant. However, two different representative distances were used, i. e., $d = \lambda/4$ and $3\lambda/4$. The orientation of the cylinders was the same as that shown in Fig. 4 of Technical Report 1522-11.

II. MEASUREMENTS

A. $d = 3\lambda/4$

Figures 1-6 show patterns for the six antenna heights. All measurements were taken with $d = 3\lambda/4$ and $l = \lambda/4$. Figure 7 shows the calculated pattern. Both the calculated and measured patterns are plotted such that the omnidirectional pattern is the circle whose radius corresponds to a relative E-field magnitude of sixty.

The patterns are self-explanatory although a few points should be emphasized. Generally speaking, the taller the scatterer with respect to the antenna, the better are the results. As the scatterer height decreases

it is observed that there is shrinkage of the major lobes and a filling in of the nulls. Not shown on the patterns but observed experimentally was the fact that as the scatterer become much smaller than the antenna, the patterns become almost omnidirectional. The most rapid changes in the patterns occur in the forward scatter direction, i. e., $\phi = 0^\circ$. This is due to increased diffraction over the top of the scatterer as the scatterer becomes smaller. Since this is the most sensitive portion of the pattern, a graph of the ratio of the antenna height, h_a , to scatterer height, h_s , versus the measured E-field, E_M , to the theoretical E-field, E_T , has been plotted for the four smallest antenna sizes, as is shown in Fig. 8. Ideally, the curves would all lie along a vertical line with the abscissa equal to one. With the exception of the curve for the short $\lambda/8$ antenna, the curves are near this "ideal curve" if the scatterer is approximately twice as tall as the antenna, i. e., $h_a/h_s = 1/2$. Figure 6 shows an unusual set of patterns in which there is a considerable enhancement in the forward-scatter direction. This is commented on further in the next section.

B. $d = \lambda/4$

Figures 9-14 show patterns for the same six antenna sizes and scatterers as before but with $d = \lambda/4$. Figure 15 shows the calculated pattern. A circle whose relative E-field magnitude is sixty corresponds to the omnidirectional pattern.

From these patterns we can draw the same general conclusions as before. That is, the taller the scatterer with respect to the antenna the better are the results. In any case a scatterer to antenna height ratio of at least 2:1 insures good results. However, for antennas $\lambda/2$ tall or less, the 2:1 requirement can be somewhat relaxed. For instance, the patterns for the $3\lambda/8$ and $\lambda/2$ antennas are very good for a ratio of almost as low as 1:1. One thing that is more noticeable with this set of patterns than with the previous set is the varying amount of interaction between the scatterer and the different antenna sizes. For example, consider the maximum field intensity measured in the back scatter direction ($\phi = 180^\circ$), in Figs. 9-11. In the first and the last figures the maximum is 100 whereas in Fig. 10 it is only 85; yet the only difference in the experimental set-up was in the antenna height itself. This is even more dramatic in Fig. 14 where considerable enhancement occurs in the forward-scatter direction for $h_s = 3\lambda/4$ and $5\lambda/8$. Also, it was observed experimentally for antennas taller than $3\lambda/4$, e. g., $h_a = \lambda$, this unusual type interaction occurred unless the scatterer was at least twice as tall as the antenna. Figure 16 is a graph similar to Fig. 8. As in Fig. 8 the ideal curve would be a vertical line whose abscissa is one. One last observation that is worthy of mention is that the patterns remain essentially the same when the finite height

hollow scatterer is open at the top as when the scatterer has a covered top. The patterns in this memorandum were all taken with a covered top.

III. CONCLUSIONS

It has been shown that the parallel wire technique is valid for predicting the far-field pattern of a vertical radiator in the presence of conducting cylinders whose height is at least twice that of the antenna. This appears to be a good rule of thumb for a wide range of antenna sizes but it can be relaxed somewhat for antennas between approximately $\lambda/4$ and $\lambda/2$ in height. Antennas taller than one wavelength were not investigated because such radiators are not usually employed in the HF region of the spectrum. In addition, it was observed that the measured pattern is changed but little by using a scatterer without a top, e.g., a smoke stack, as opposed to a scatterer with a top, e.g., an island on an aircraft carrier.

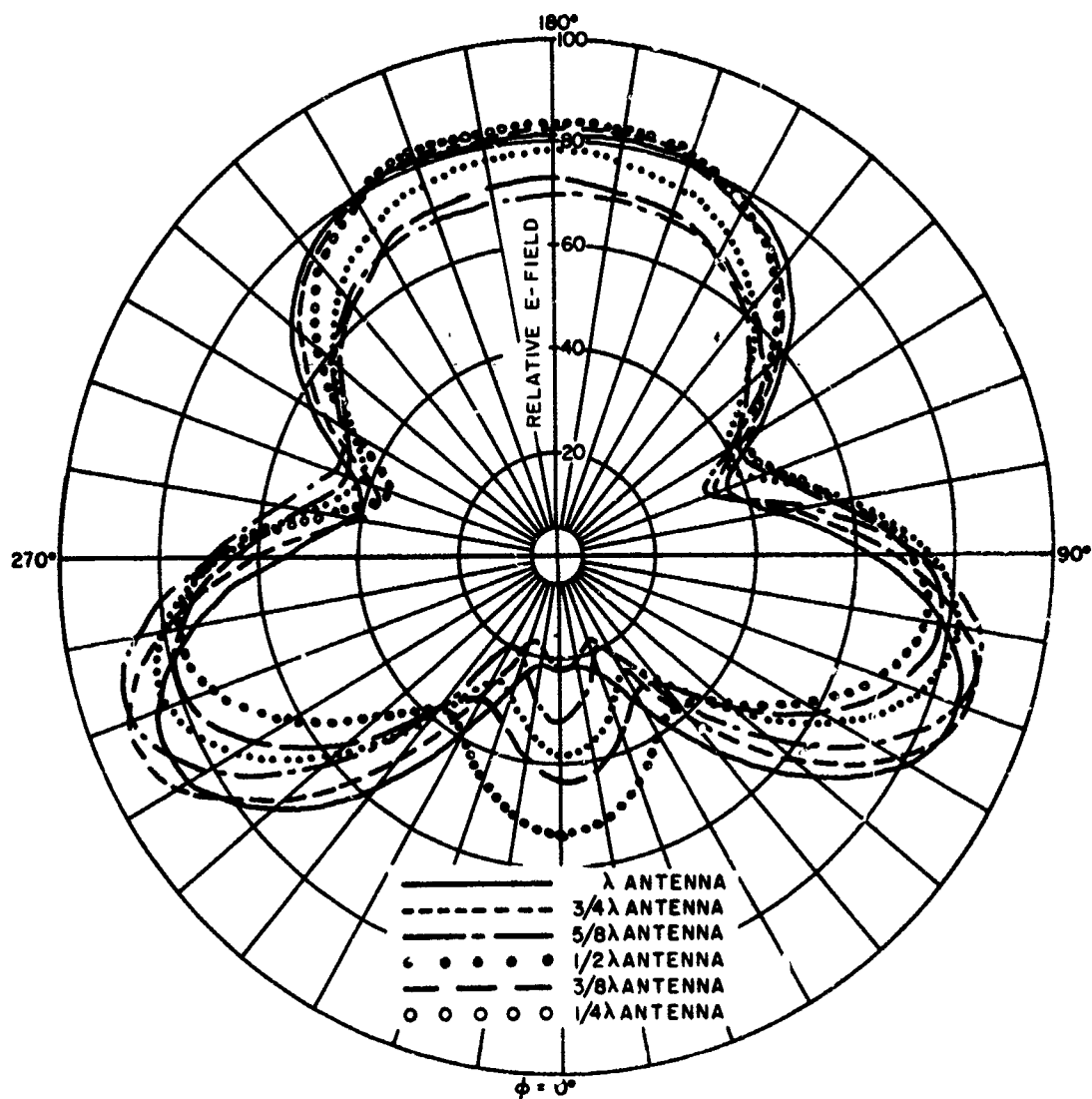


Fig. 1. $h_a = \frac{1}{8}\lambda$, $d = \frac{3}{4}\lambda$.

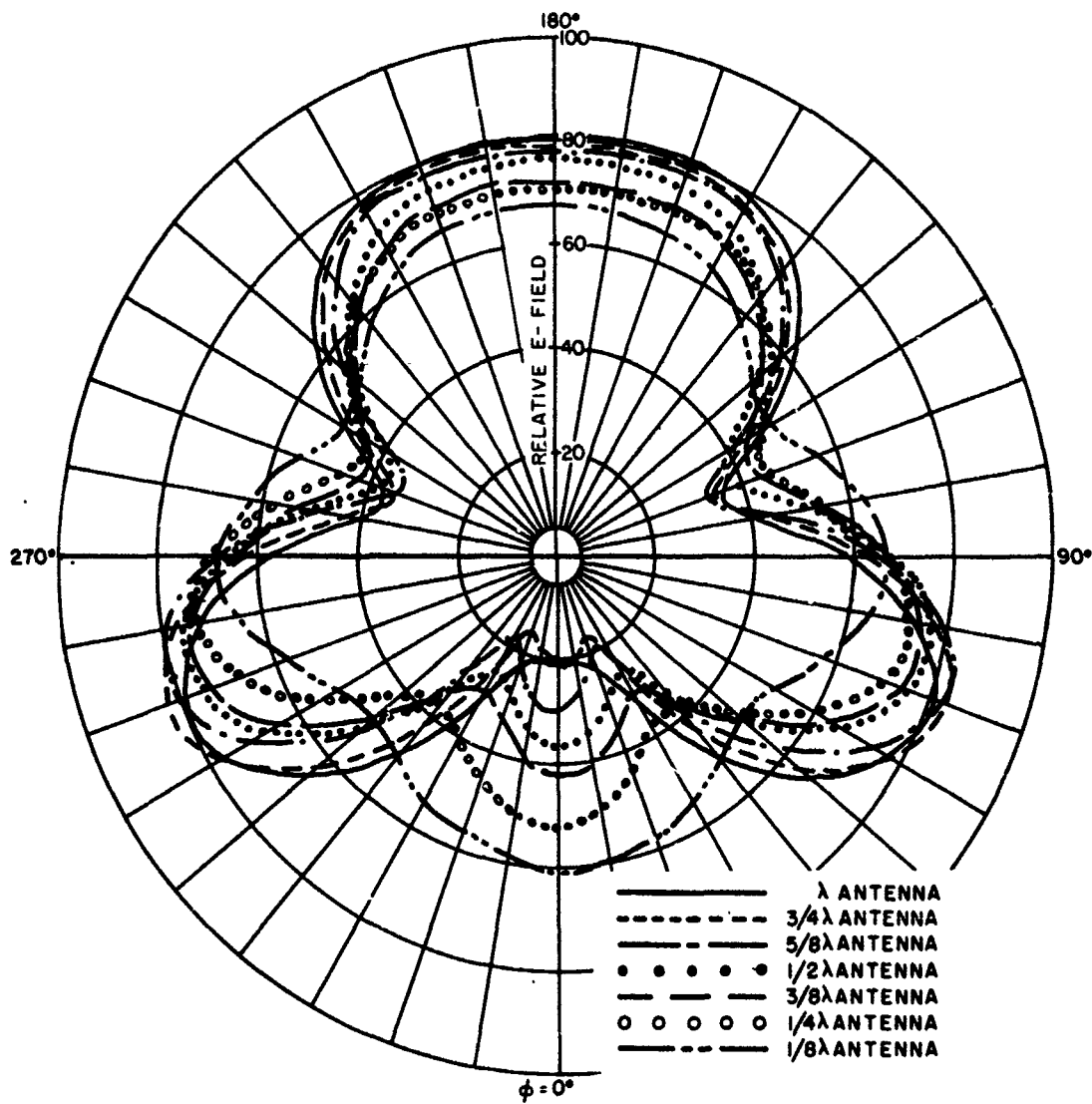


Fig. 2. $h_a = \frac{1}{4}\lambda$, $d = \frac{3}{4}\lambda$.

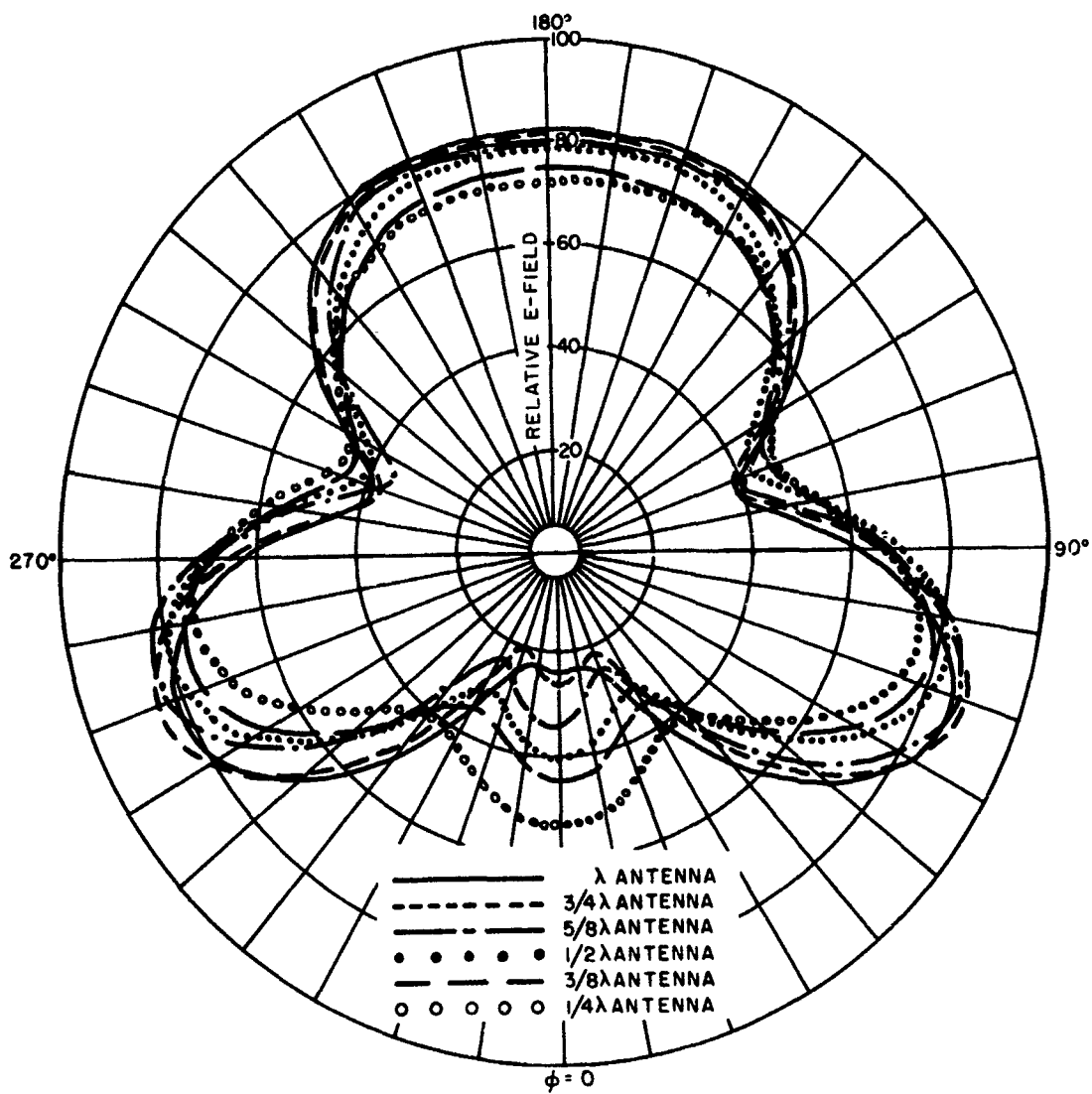


Fig. 3. $h_a = \frac{3}{8}$, $d = \frac{3}{4} \lambda$.

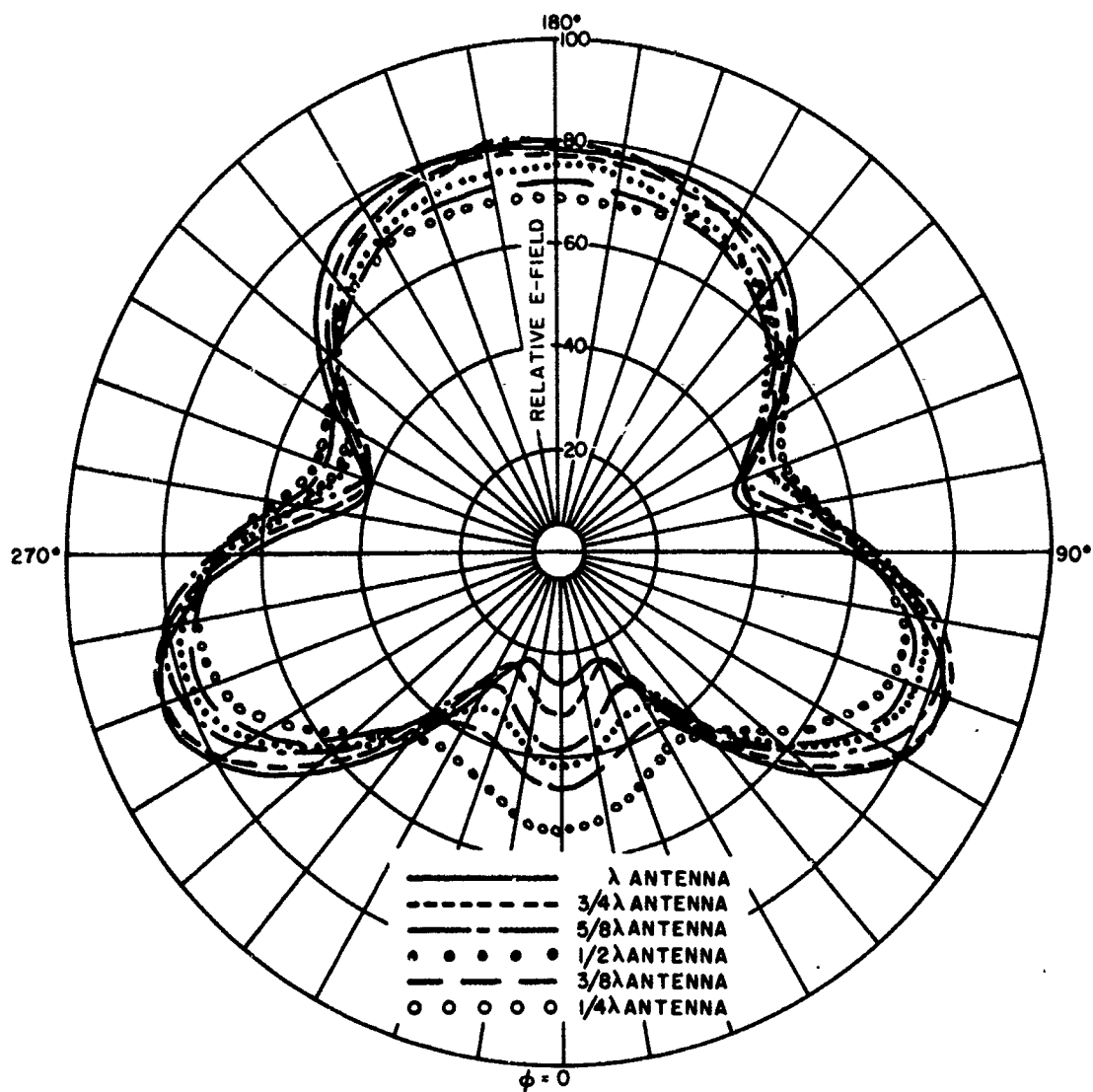


Fig. 4. $h_a = \frac{1}{2}\lambda$, $d = \frac{3}{4}\lambda$.

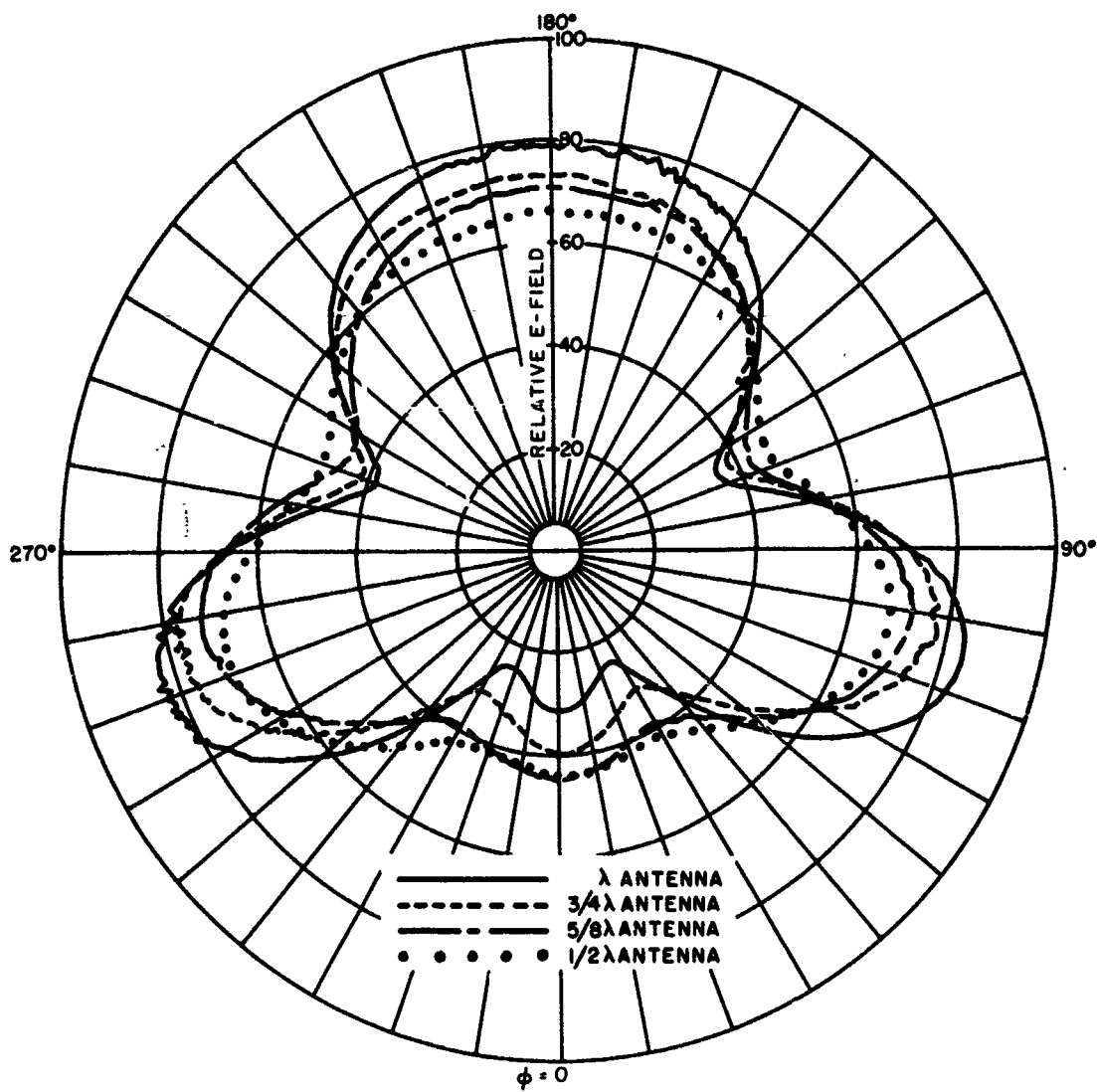


Fig. 5. $h_a = \frac{5}{8}\lambda$, $d = \frac{3}{4}\lambda$.

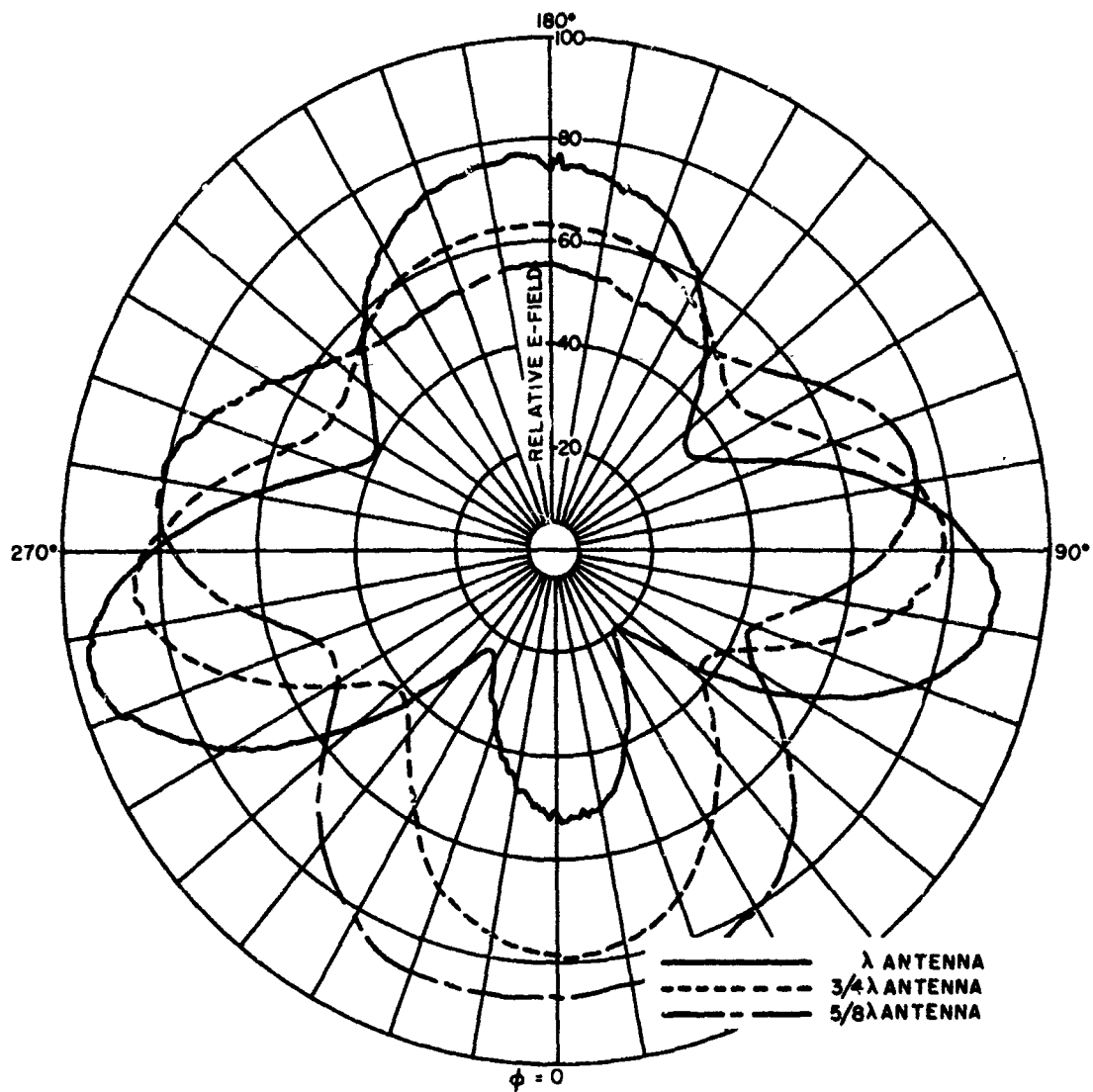


Fig. 6. $h_a = \frac{3}{4}\lambda$, $d = \frac{3}{4}\lambda$.

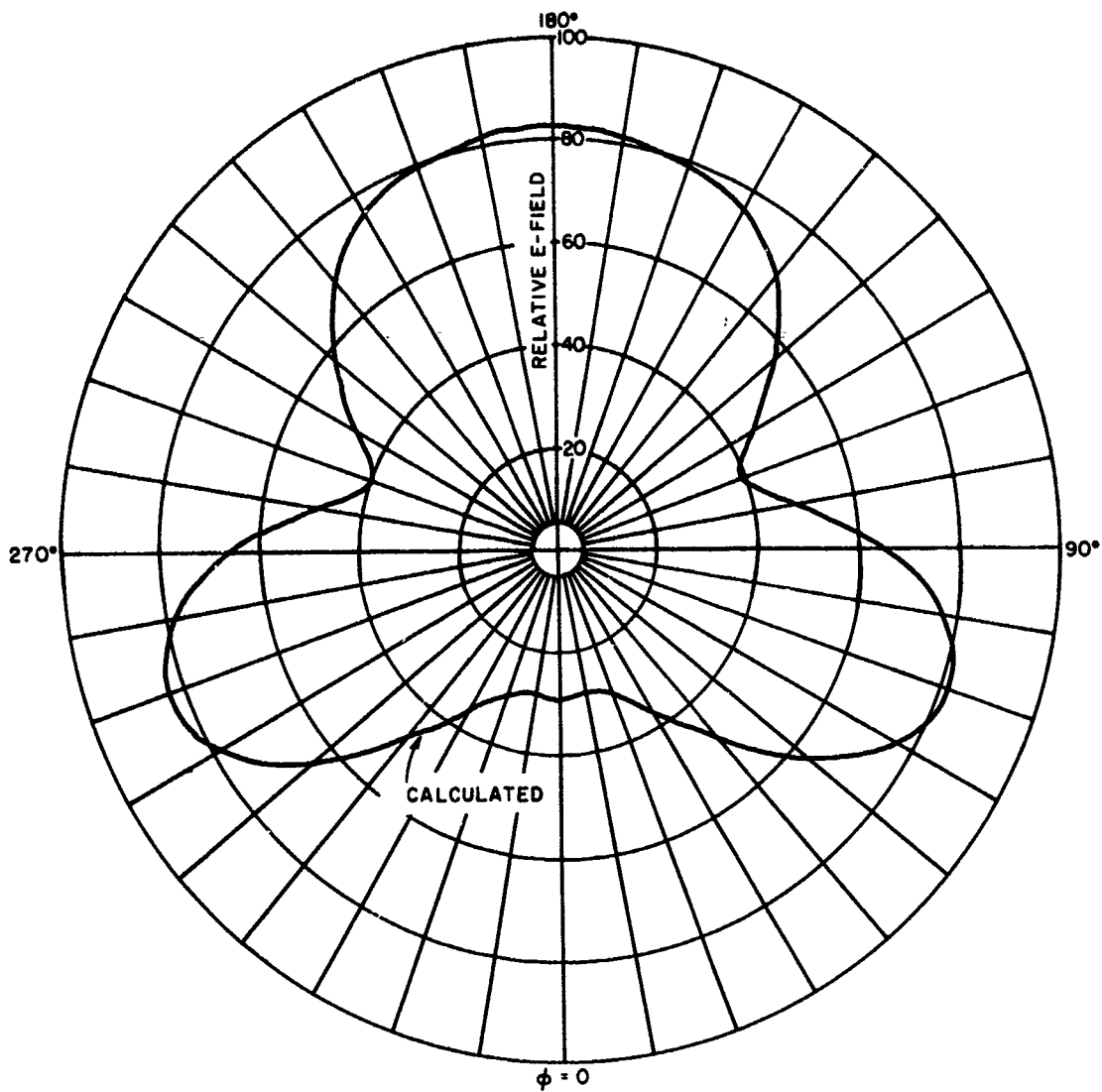


Fig. 7. Calculated pattern, $d = \frac{3}{4} \lambda$.

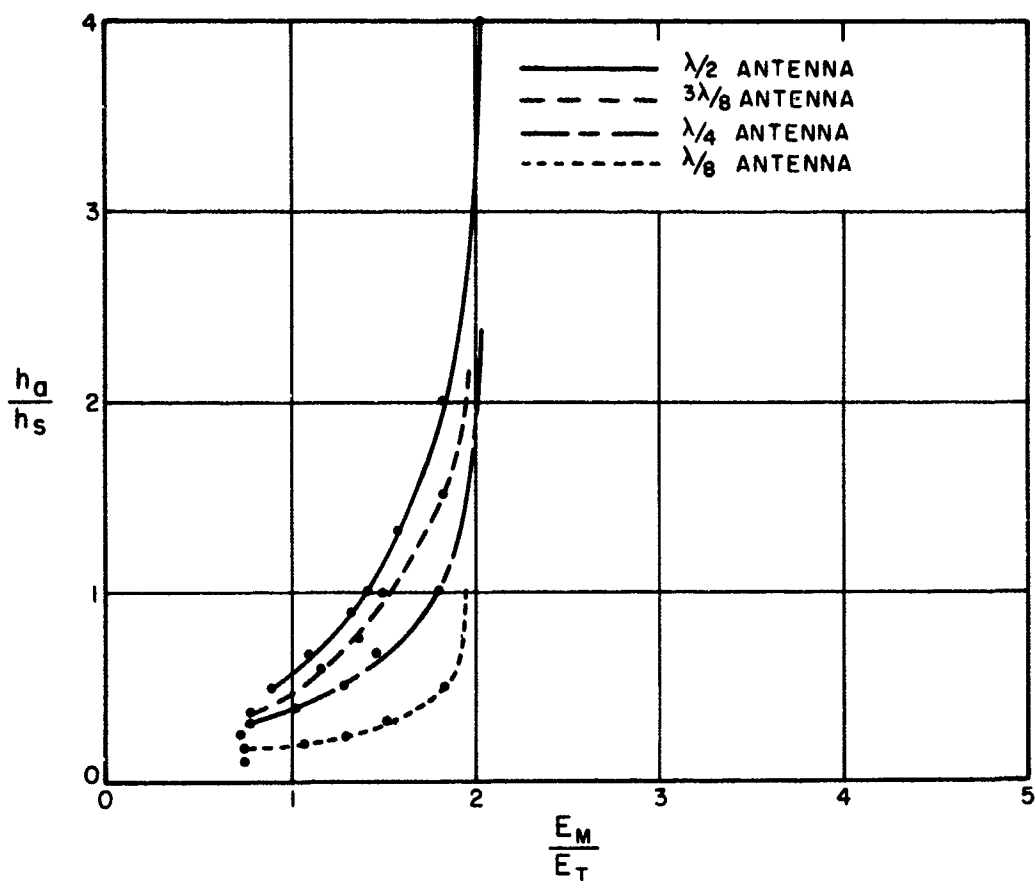


Fig. 8. Graph of h_a/h_s ratio versus E_M/E_T ratio for $\phi = 0^\circ$, $d = \frac{3}{4}\lambda$.

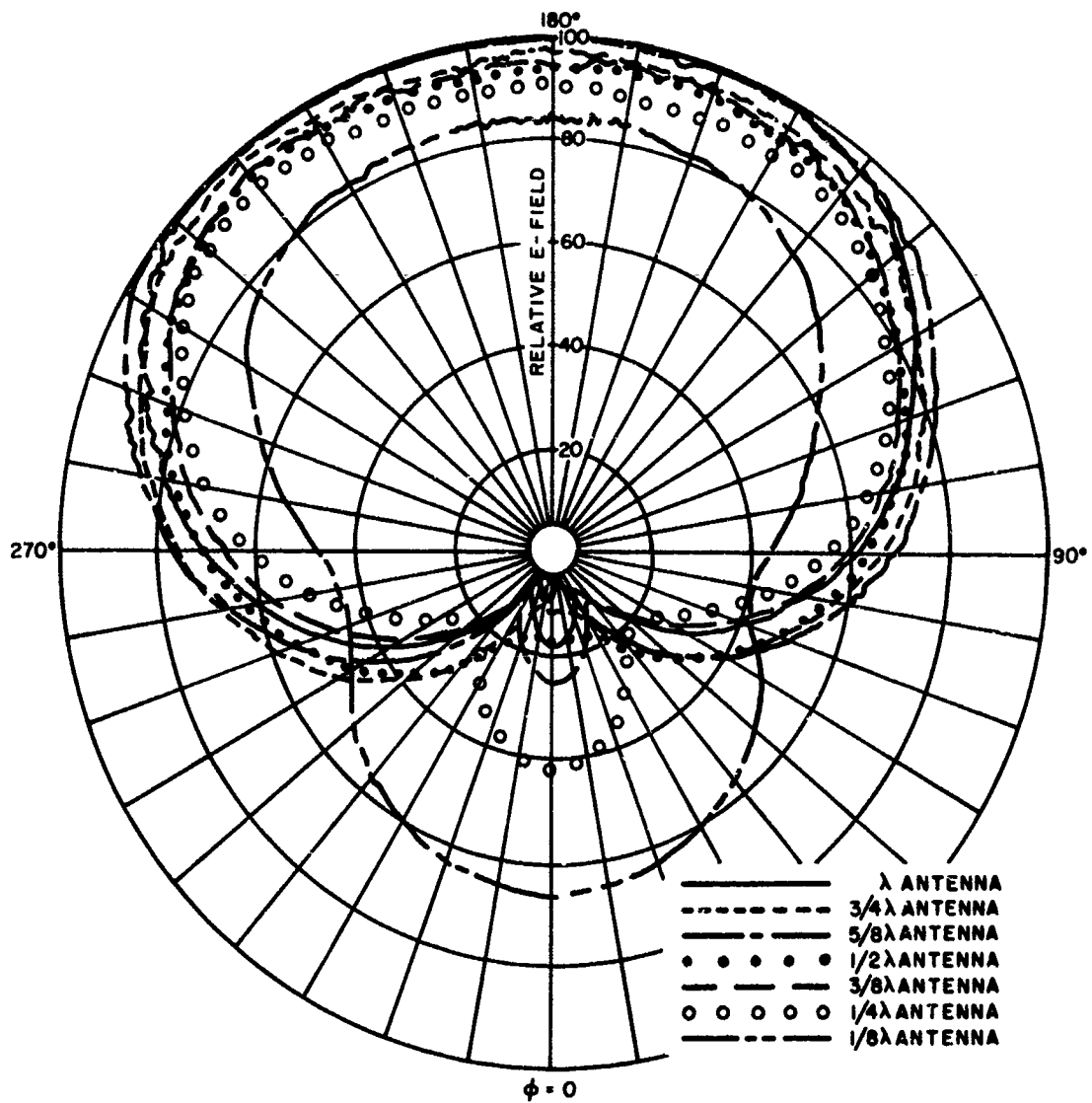


Fig. 9. $h_a = \frac{1}{8}\lambda$, $d = \frac{1}{4}\lambda$.

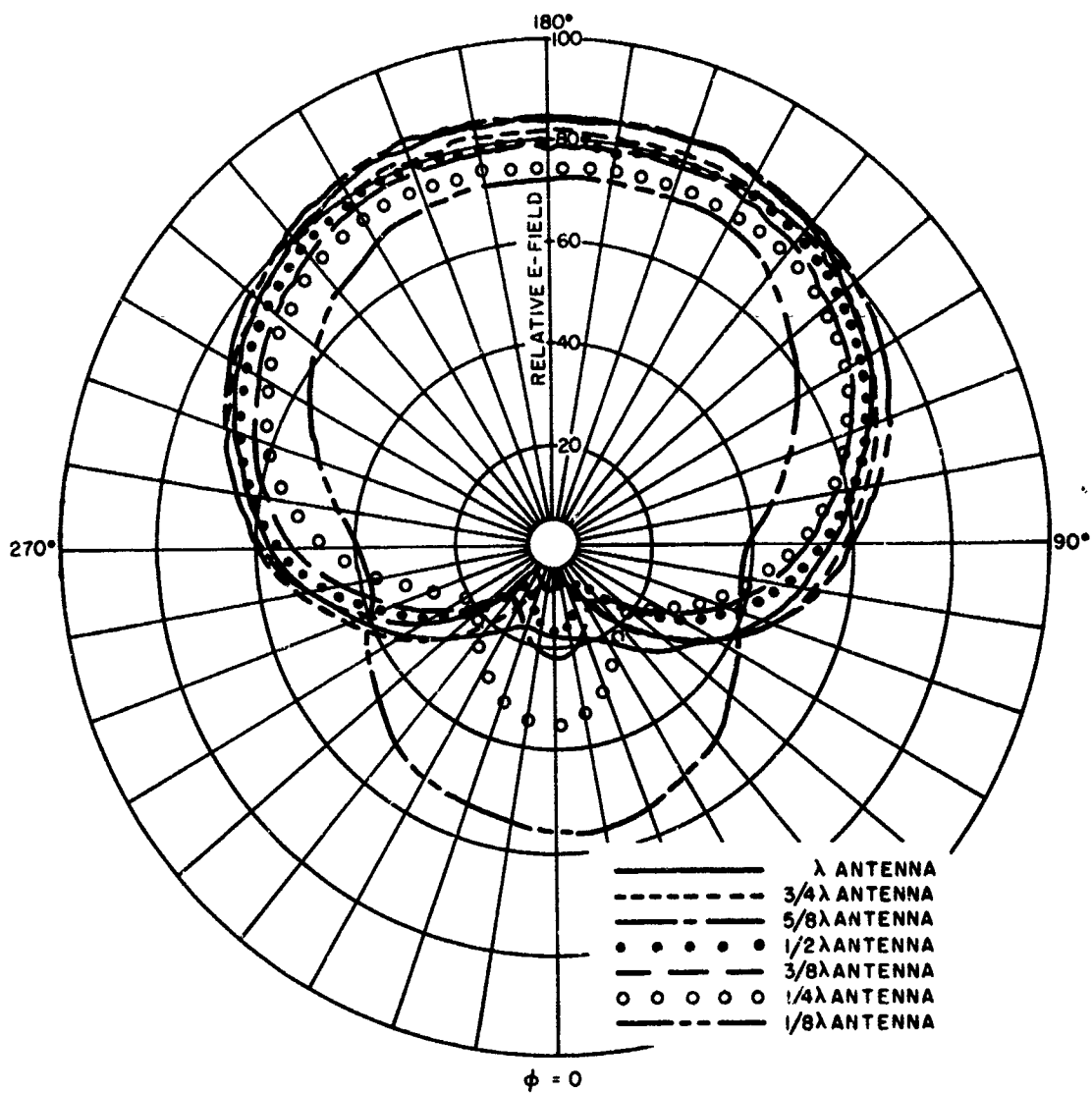


Fig. 10. $h_a = \frac{1}{4}\lambda$, $d = \frac{1}{4}\lambda$.

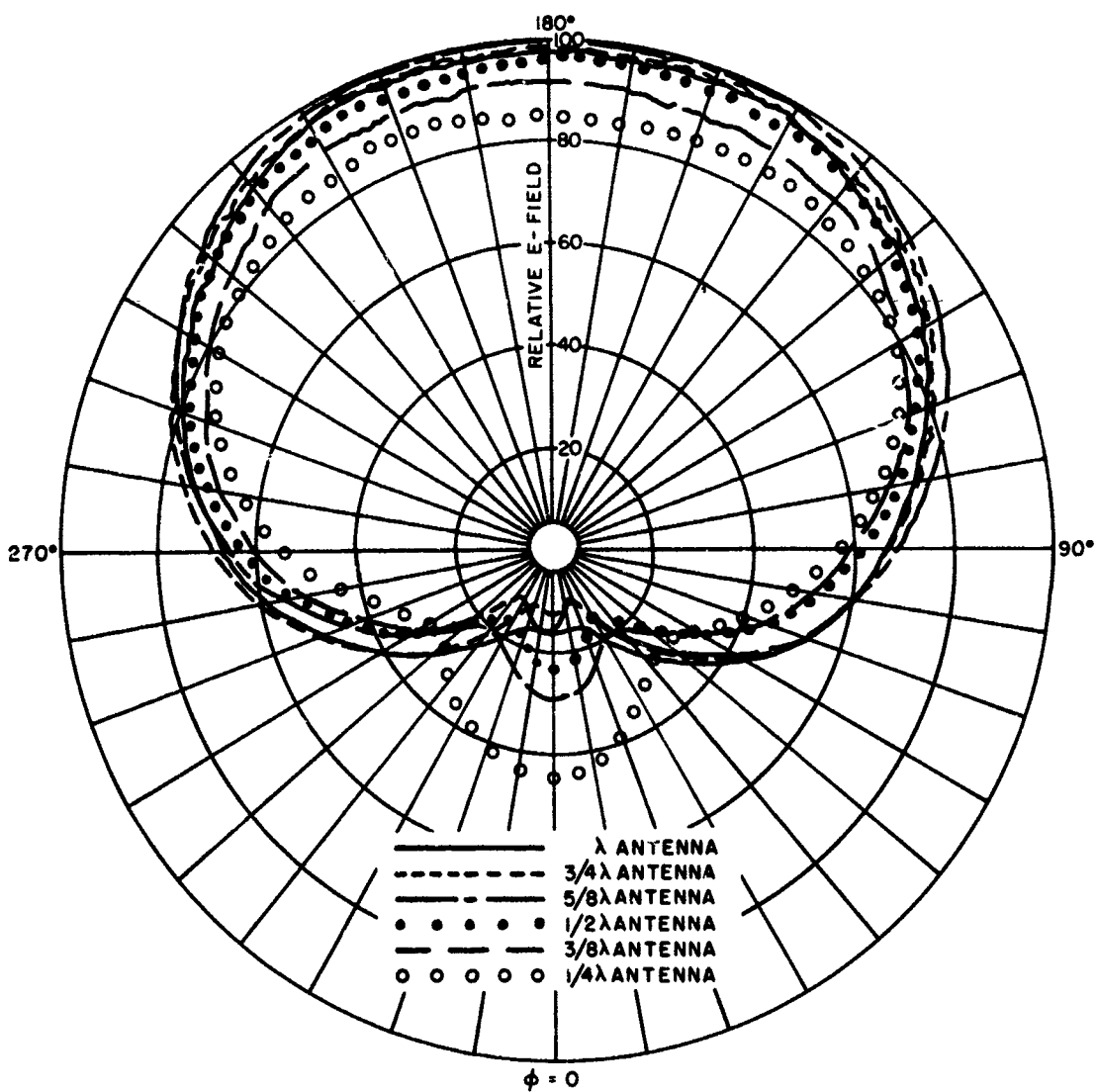


Fig. 11. $h_a = \frac{3}{8}\lambda$, $d = \frac{1}{4}\lambda$.

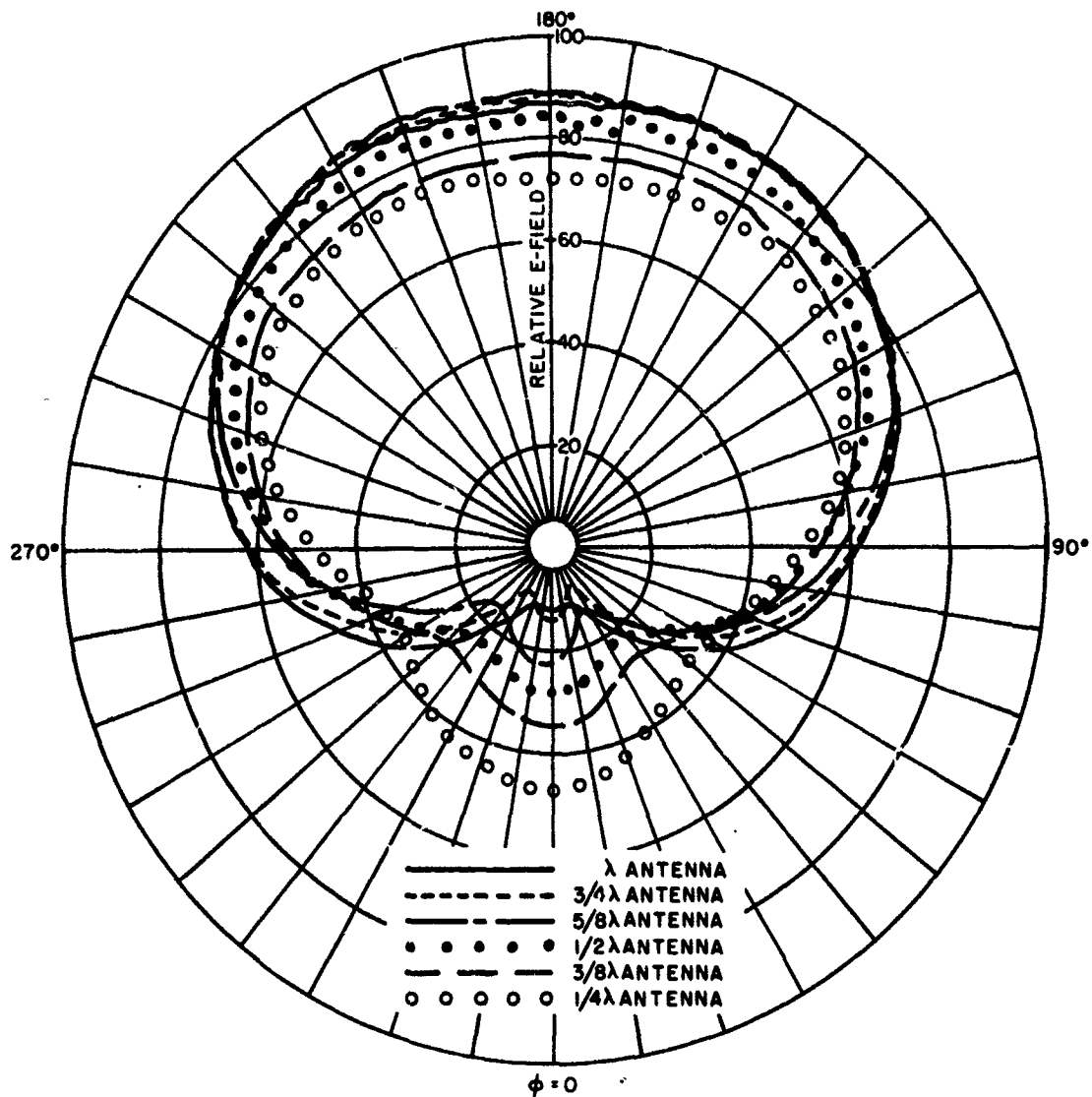


Fig. 12. $h_a = \frac{1}{2}\lambda$, $d = \frac{1}{4}\lambda$.

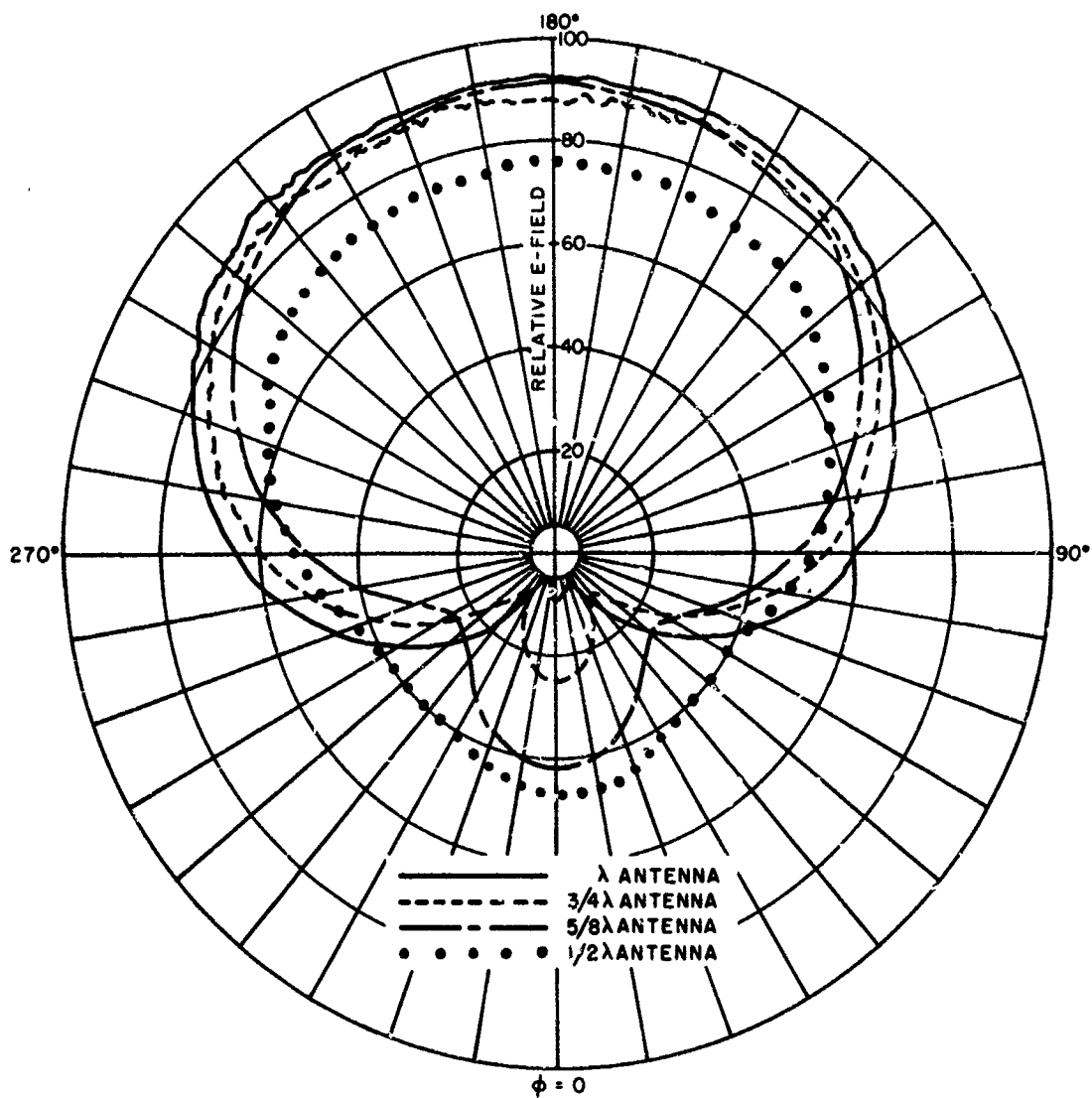


Fig. 13. $h_a = \frac{5}{8}\lambda$, $d = \frac{1}{4}\lambda$.

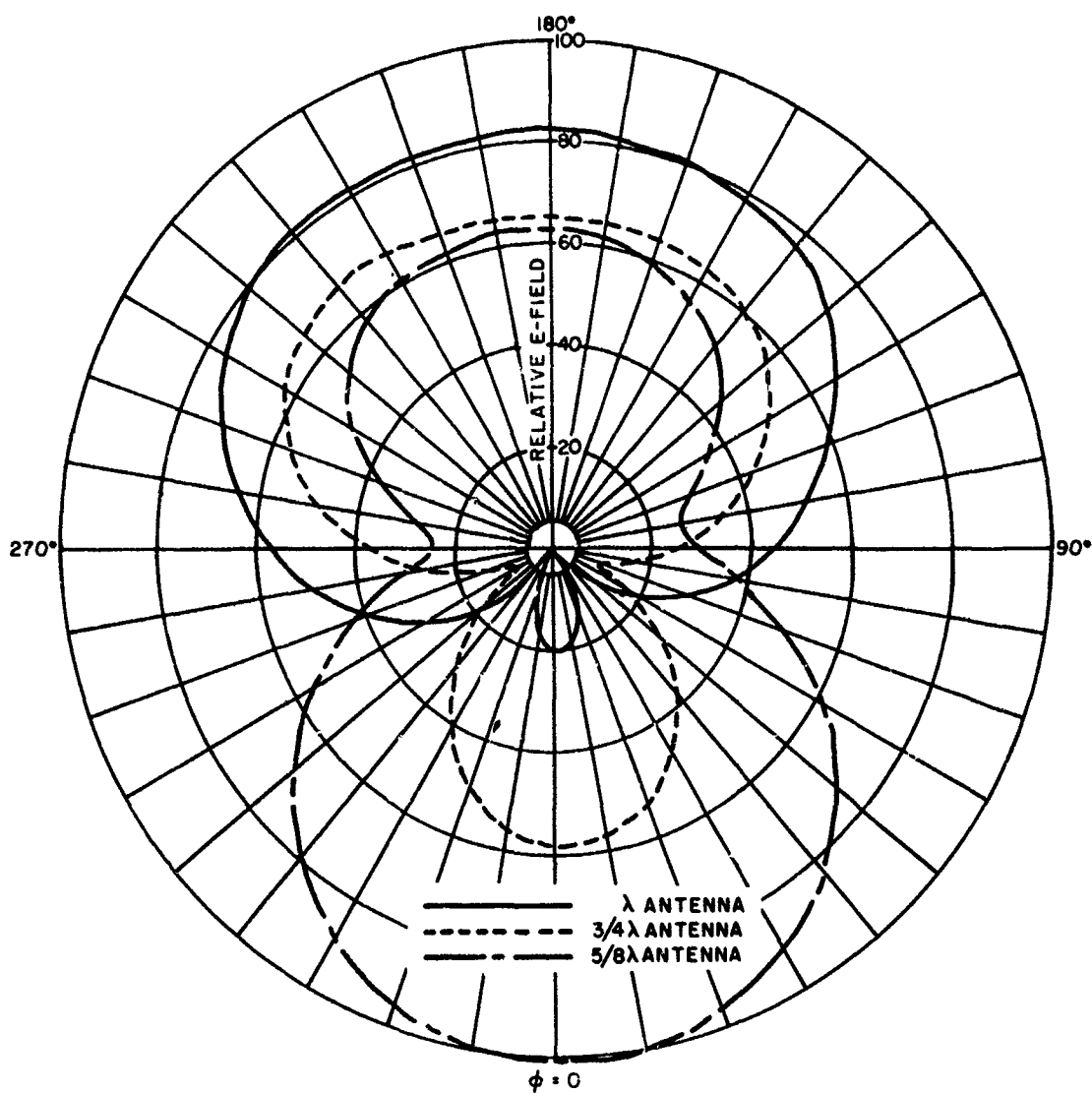


Fig. 14. $h_a = \frac{3}{4}\lambda$, $d = \frac{1}{4}\lambda$.

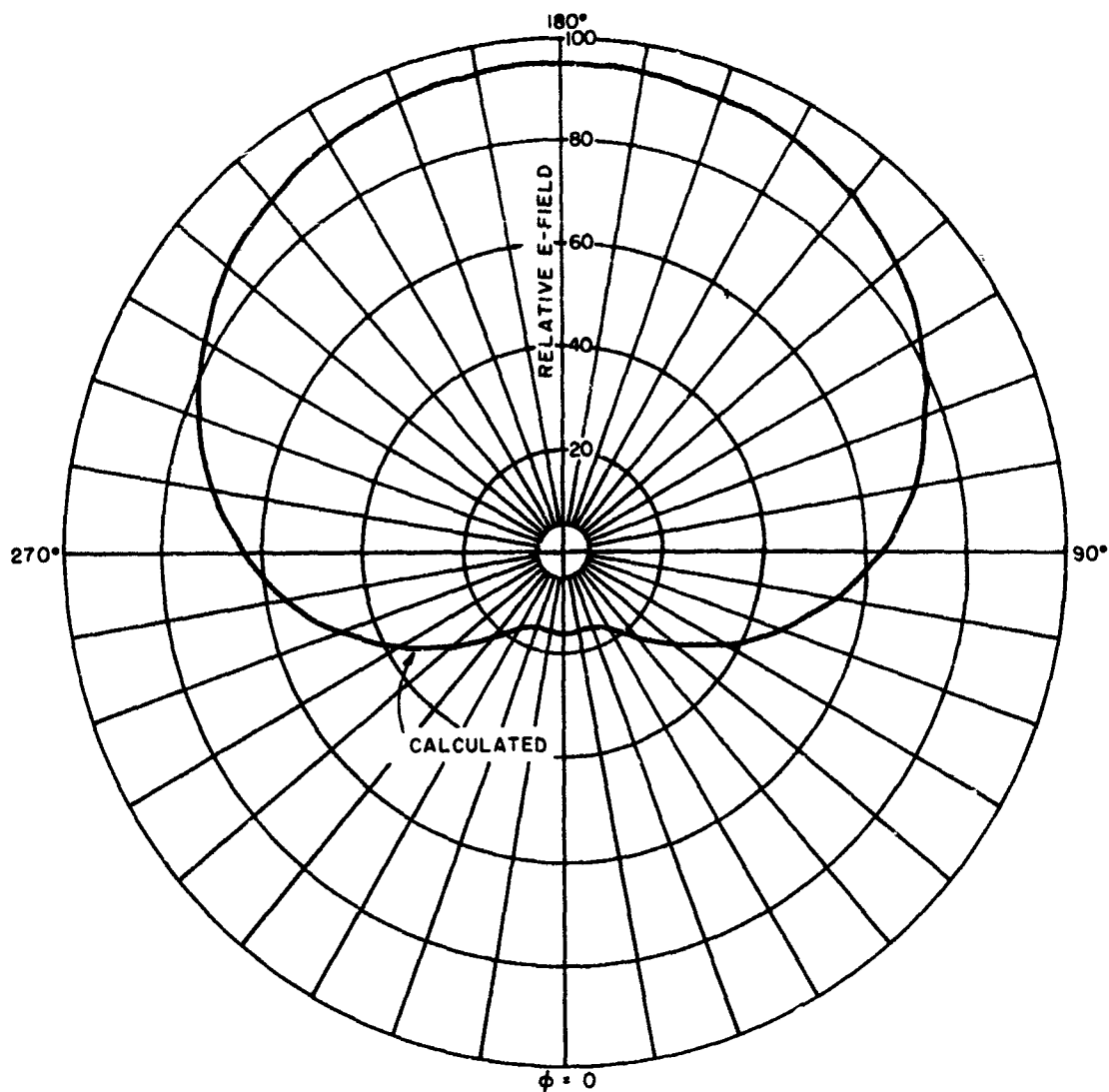


Fig. 15. Calculated pattern, $d = \frac{1}{4} \lambda$.

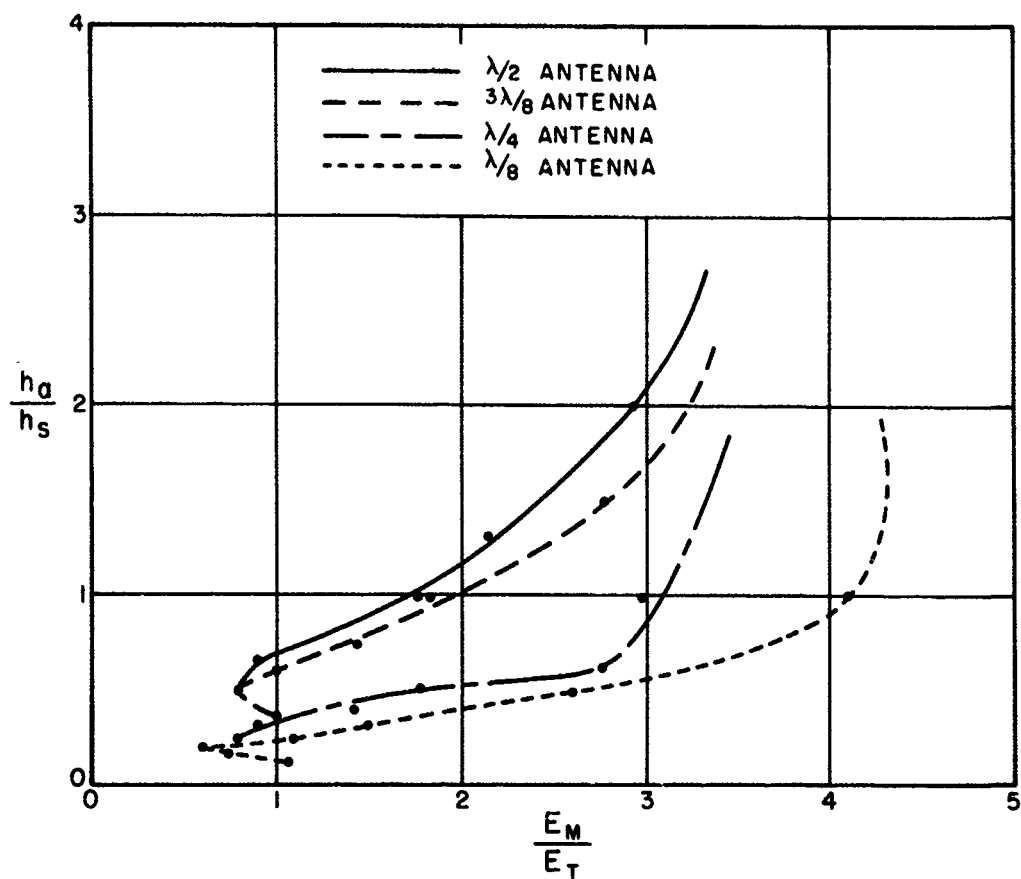


Fig. 16. Graph of h_a/h_s ratio versus E_M/E_T ratio for $\phi = 0^\circ$, $d = \frac{1}{4}\lambda$.

REFERENCES

1. Thiele, Gary A., Pattern Handbook, Vol. I "Far-Field Pattern Prediction for Shipboard Antennas," Report 1522-11, 31 March 1965, Antenna Laboratory, The Ohio State University Research Foundation; prepared under Contract N 123(953) -31663A, United States Navy Electronics Laboratory, San Diego, California.